EXPERIMENTAL INVESTIGATION OF BEHAVIOUR OF A TYPICAL RIVETED FINITE JOINT

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SUMMARY

The behaviour of a typical finite riveted joint under simple tensile loading is experimentally investigated. Four types of specimens are tested to find out the effect of rivet size and configuraation on joint strength. It is observed, that the rivet size and configuration do not have significant effect on joint strngth, since the joint strength is mainly controlled by the bending stresses. It is also observed that the finite width of the hinge plate brings additional forces into joint region which causes lateral bending of the joint.

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1. INTRODUCTION

Finite riveted joints are used in many engineering situations like nose cone attachment with fuselage, conopy attachment with the fuselage in aircraft and nose radome attachment with the central section in pods. Here a typical joint between nose radome and central section is pod structure has been taken for an experimental investigation of its behaviour under inplane loading. For efficient design of this type of joint and proper selection of materials for various components of the joint, the role and behaviour of each component of this joint has to be known clearly. The joint behaviour can be determined by conducting tests on coupon specimens or by theoretical analysis using finite element methods(FEM). Theoretical analysis of this type of joint even by FEM is fairly complicated and needs validation by experimental methods. Hence, experimental investigation on coupon specimens is chosen here. The role of this joint is to transfer the nose radome loads to the central section. This load is not transferred along the entire circumference of the radome. It is transferred at 3 points in a finite width. The typical load transfer points are shown in Fig.1. The special behaviour of this joint comes from this load transfer at a finite number of points in a finite width at each point. In this investigation, the load carrying capabilities of joint specimens is experimentally determined. The dependence of joint strength on the rivet size and configuration is also investigated. In all, twelve joint specimens consisting of four different rivet configurations are fabricated and tested. Tweleve strain gauges are fixed on each specimen. Uniaxial tensile tests are conducted on these specimens in 250 KN Servo Hydraulic Computer Controlled Instron Testing Machine. The response of strain gauges are monitored with the help of multi channel data logging system. The test results indicate that the bending stresses are predominant and play a crucial role in load transfer from radome to the central section of pod.

2. FABRICATION OF JOINT SPECIMENS

The joint specimen consists of the following parts:

1. Glass-epoxy sheet, 2. Aluminium stiffener
3. EN 24 hinge plate and 4. Aluminium rivets

The details of the stiffener and joint specimen are indicated in Figs.2 and 3 respectively. Hinge plate, stiffener and composite sheet are jointed together by means of rivets as shown in Fig.3.

E glass epoxy sheet is fabricated using 0.18 mm plane weave woven fabric and high temperature curing epoxy system(LY 556 and HT 972). The fabrication technique simulates the pressure bag moulding technique, usually used in the fabrication of radomes. The curing schedule is as follows:

Pressure	= 0.689 MPa (100 psi)
Temperature	= 120 deg.
Time	= 3 hours

Fibre orientation and stacking sequence of twelve layers of woven fabric, required to give 2 mm thickness which is a typical thickness used for radome fabrication.

The rivets selected here are used after the heat treatment, which is as follows:

Soaking the rivets at 495 deg. for 35 minute, quenching in the water at 20 deg. and spirit dip before cold storage.

Twelve specimens of four different types are fabricated. The different configurations are shown in Figs 4 to 7. These different configurations are selected with the view of studying the influence of rivet size and cofiguration on joint strength. Hence only these parameters are varied in the different joint specimens. That is: the adherends (composite sheet,stiffener and hinge plate)are not changed from specimen to specimen. Also the attachment details of composite sheet and the stiffener is maintained constant in all the specimens. This is because the hinge plate region is considered to be the critical portion of the joint. Fig.4 shows the Type '1'joint specimen. Fig.5 shows type '2' specimen where rivets of lower diameter are used in one row Fig.6 shows type '3' specimen where rivets of lower diameter are used in two rows. Fig.7 shows type '4' specimen where a different configuration of rivets is used.

3. TESTING AND RESULTS

Fig.8 indicates the joint specimen with additional end fixture for applying uniaxial tensile load through pin loading. Fig.9

shows the photograph of the specimen with the end fixtures. The specimens with the help of this fixture were tested in 250 KN Instron testing machine. Fig.10 shows the photograph of the specimen when it is mounted on the testing machine.Three replicate specimens were tested for each type.

All the specimens were strain gauged to study the response of joint under load. Fig.11 shows the position of 12 strain gauges. In type '1' failure in all the three specimens occurred by cracking of the composite sheet along the lower row of rivets. This is shown in Figs. 12 and 22.

There is a considerable amount of bending in this joint at hinge plate due to eccentricity of loading as shown in Fig.13.

Variation of strains with applied load is shown in Figs 14 and 15. In the absence of bending, the surface strain at position 2 (Fig.15) will be higher than the one at position 4. In the present situation where bending is existing, the surface strains recorded are the superposition of tensile strains and bending strains. At position 2, the bending being maximum, the compressive strain due to bending is quite high and as a result, the net surface tensile strain is quite low. Whereas on the opposite side of composite sheet, where no strain gauges could be mounted, the bending will give tensile strain and hence surface strain at position 2 will be much higher, resulting in the tensile failure of the sheet. It is conjectured that crack initiated on this side and propagated across the thickness of the sheet to the other side. This observation is confirmed by behaviour of strain at position 2 at higher load. It is noted from Fig.15 that the strain at position 2 starts increasing beyond a value of load near to failure.

Since the failure is very sudden the failure strain at the gauge no.2 could not be recorded. Because of the bending effect, even though strain at gauge no.2 is less than the strain at gauge no.4, the failure occurred at gauge no.2 location.

In Fig.16,geometry of the specimen type '1' before and after test is shown. It can be clarly seen at the cracked location(X-X), that rivet heads are rotated such that on one side it pierced into the plate and the other side it lifted from the surface, confirming the above discussed bending behaviour. The hinge plate is also subjected to large bending strains, this can be easily noticed from the fact, that all the strain gauges fixed on the hinge plate were showing compressive strains in the entire load range.

Apart from this, the joint is also subjected to large compressive stress perpendicular to the loading direction in the same plane. All the tested specimens were permanently deformed at the hinge side. After the test,all the aluminium stiffeners were deformed to a curved plate (Fig.24) This is the general behaviour of the joint specimens in all the 4 types. Figs 17 and 18 give the strains at various locations near the hinge plate of type 2 specimen. In type 3 specimen failure is not in composite plate. The specimen failed because of shearing of rivets. The typical strains at various locations near the hinge plate of specimen type 3 are given in Figs. 19 and 20. Unlike in Fig.13, the strain of gauge no.2 near failure does not rise sharply. This confirms the earlier observation. Figs.21 and 22 give typical strains in type 4 specimen. Among the specimens where failure is in composite sheet, Type-4 has given the least failure load. This is because of the type of rivet configuration, which decreases the section modulus of composite sheet by restricting the width of the bending zone. This causes more bending strains for the same bending moment and hence results in lower failure load.

Table 1 gives the maximum, minimum and average failure load for each type of specimen. Except type 3 specimen all the other specimens failed at 2700 Kg. approximately. This is because bending strains are more predominent. Among all the configurations, Type-2 is having slightly higher failure load, and less scatter.

4. CONCLUSIONS

Following observations are made from the test results:

1. The presence of stiffner plate is causing more eccentricity in loading and hence more bending. The main purpose of the stiffener plate is too resist the lateral bending.

2. The failure of joint in composite sheet is not net section failure. This is because of the fact that the reduction in diameter of rivets to increase the net section area did not result in increase in failure load.

3. As there is considerable bending in the joint, the failure is predominatly controlled by bending stresses and hence the rivet configurations considered here do not influence the failure load.

It is noted that the stiffener plate has undergone permanent deformation due to lateral bending of joint. From the present study, suggetions for improving the joint design are mentioned below:

1. The material of the stiffener should be of high modulus and high strength.

2. The thickness of stiffener should be as small as possible

3. The material of hinge plate should be of high strength and low modulus and the thickness of hinge plate should be low.

4. Composite sheet should be as thin as possible and lateral strength of the sheet should be high.

5. The number of rivets at the bottom row of hinge plate should be more.

ACKNOWLEDGEMENT

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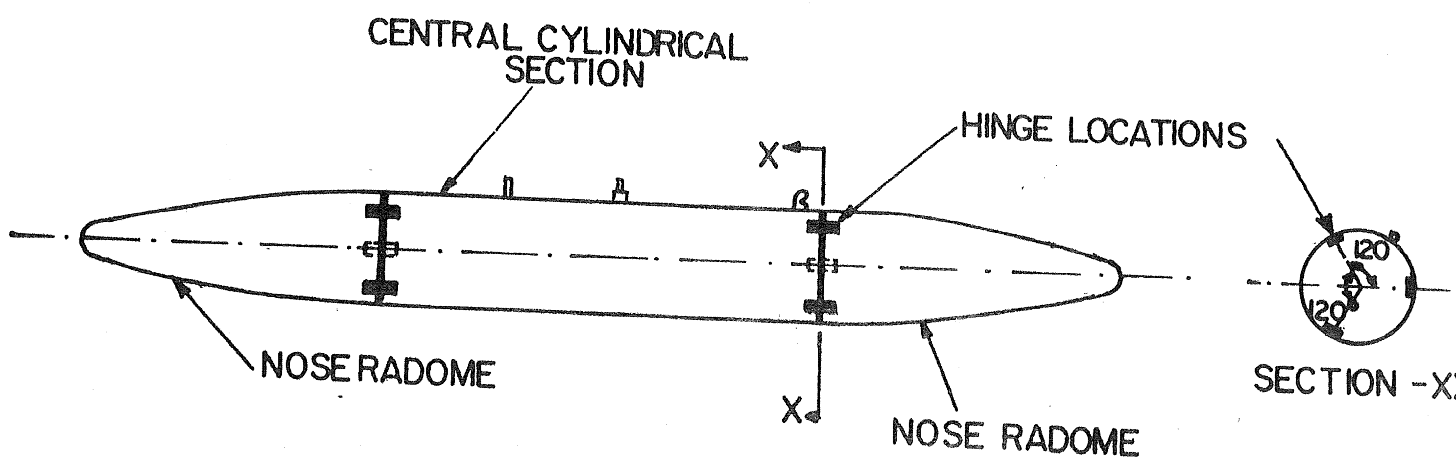

FIG. I. HINGE LOCATIONS ON THE POD

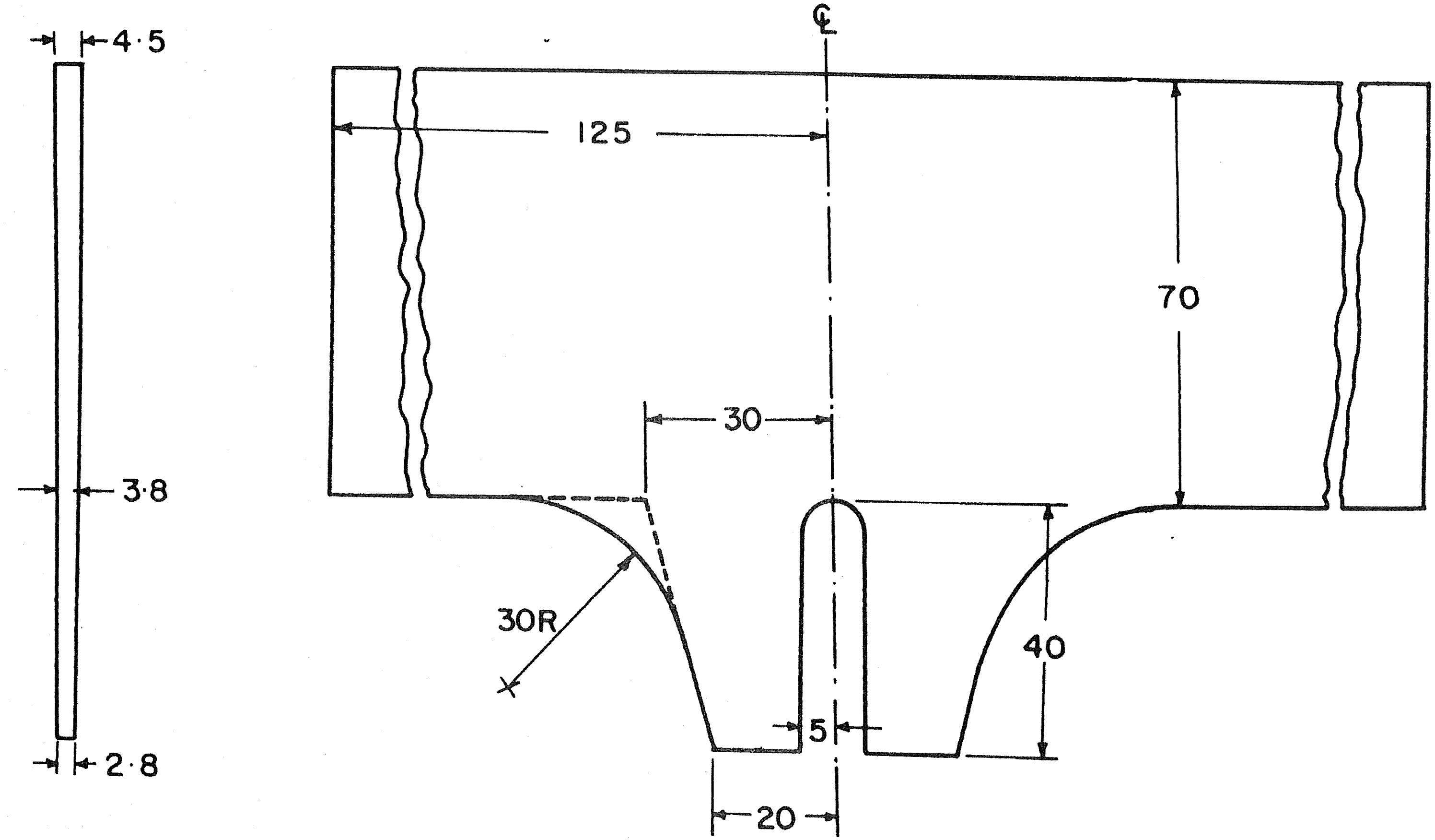

FIG. 2 . DETAILS OF ALUMINIUM STIFFENER

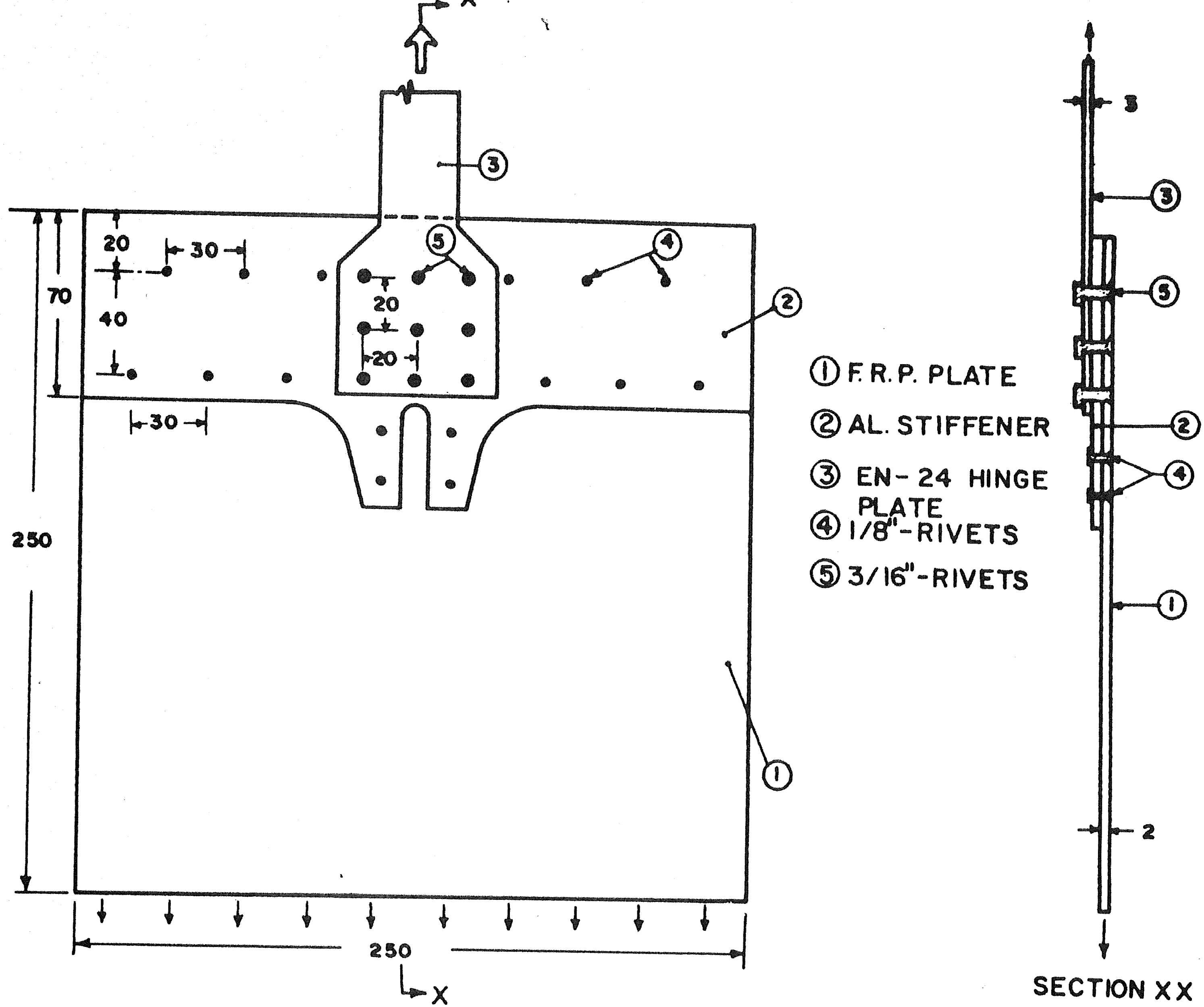

FIG. 3. DETAILS OF THE JOINT

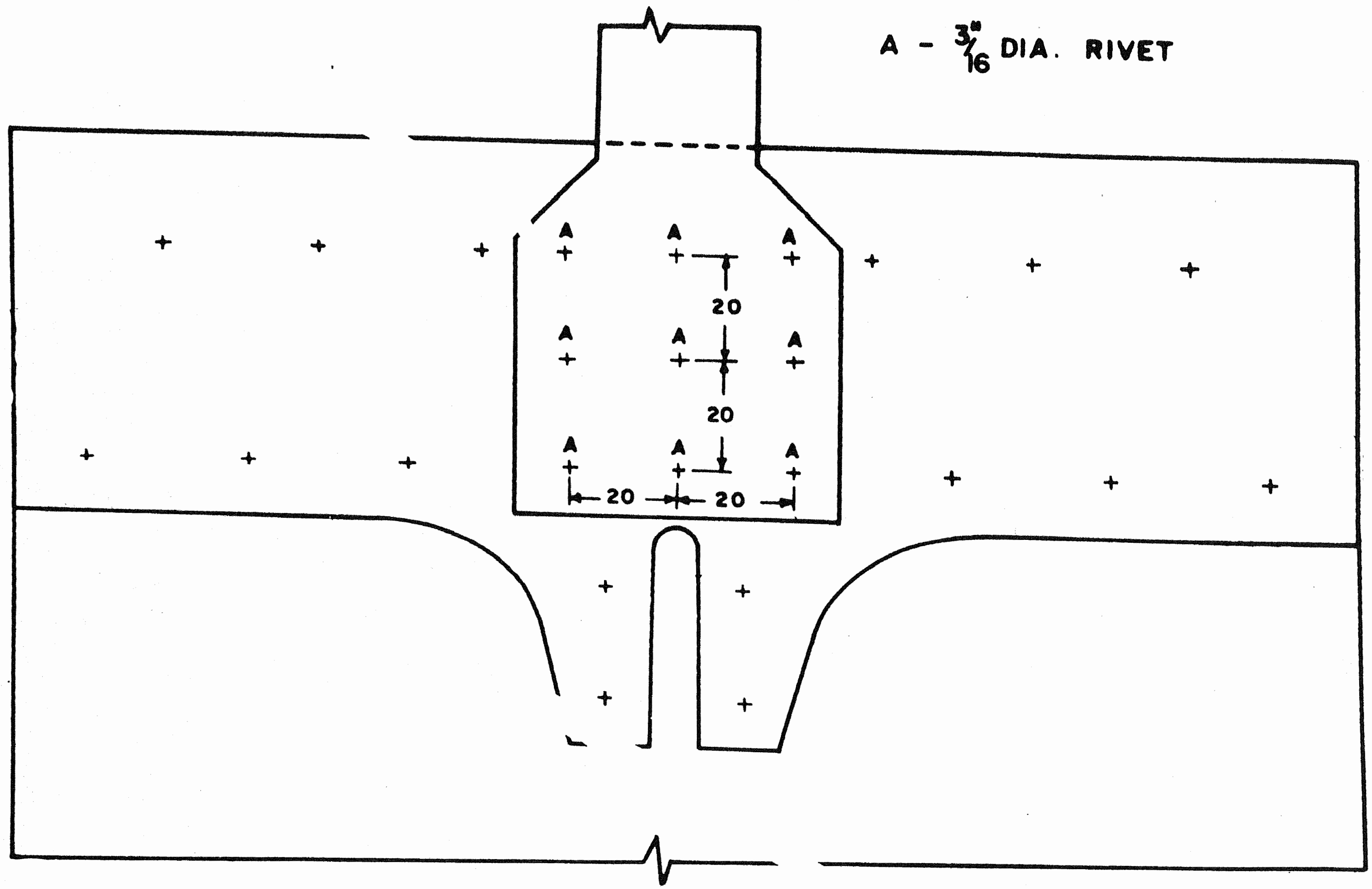

FIG. 4. JOINT SPECIMEN TYPE 'I'

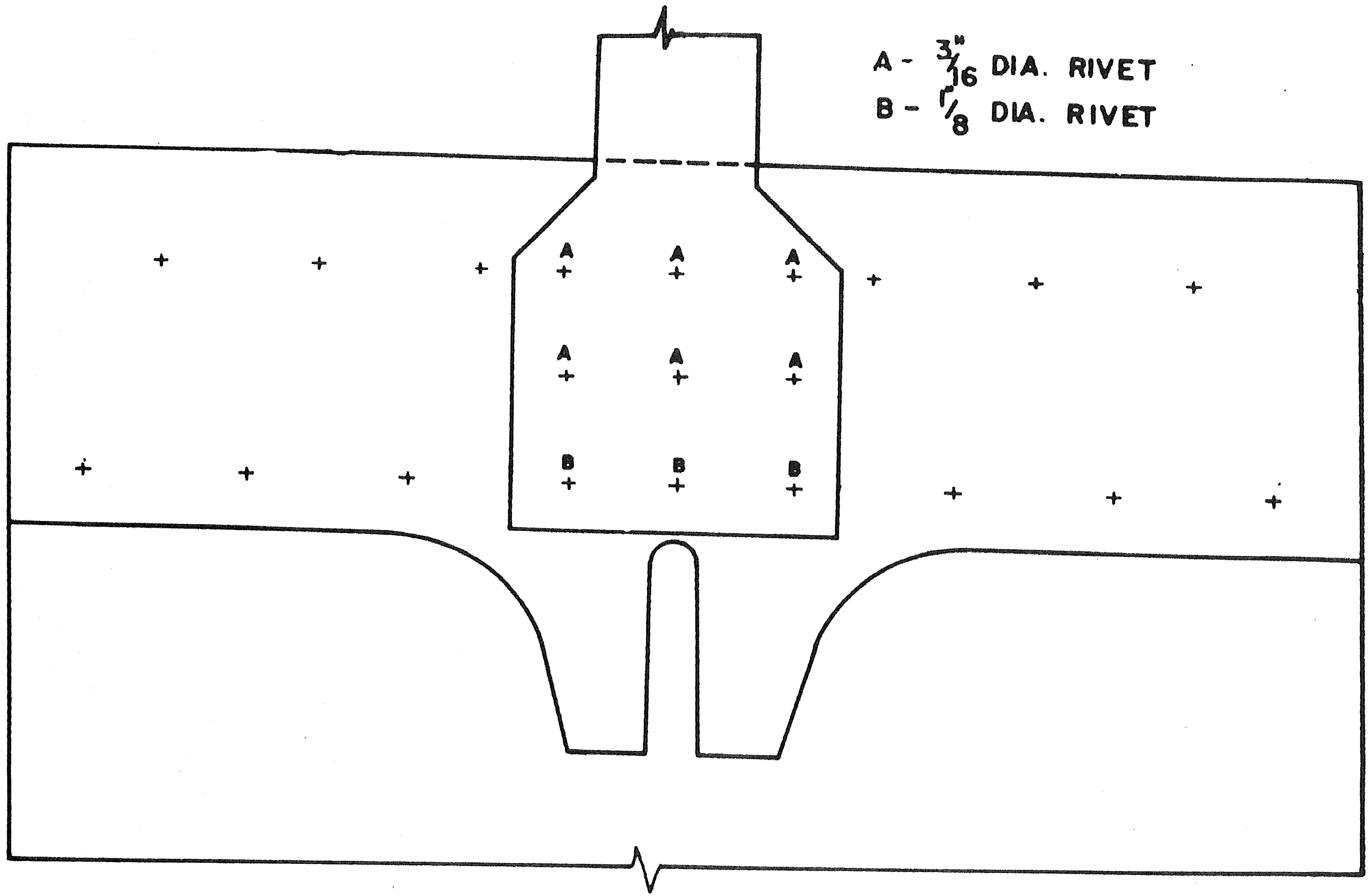

FIG. 5. JOINT SPECIMEN TYPE '2'

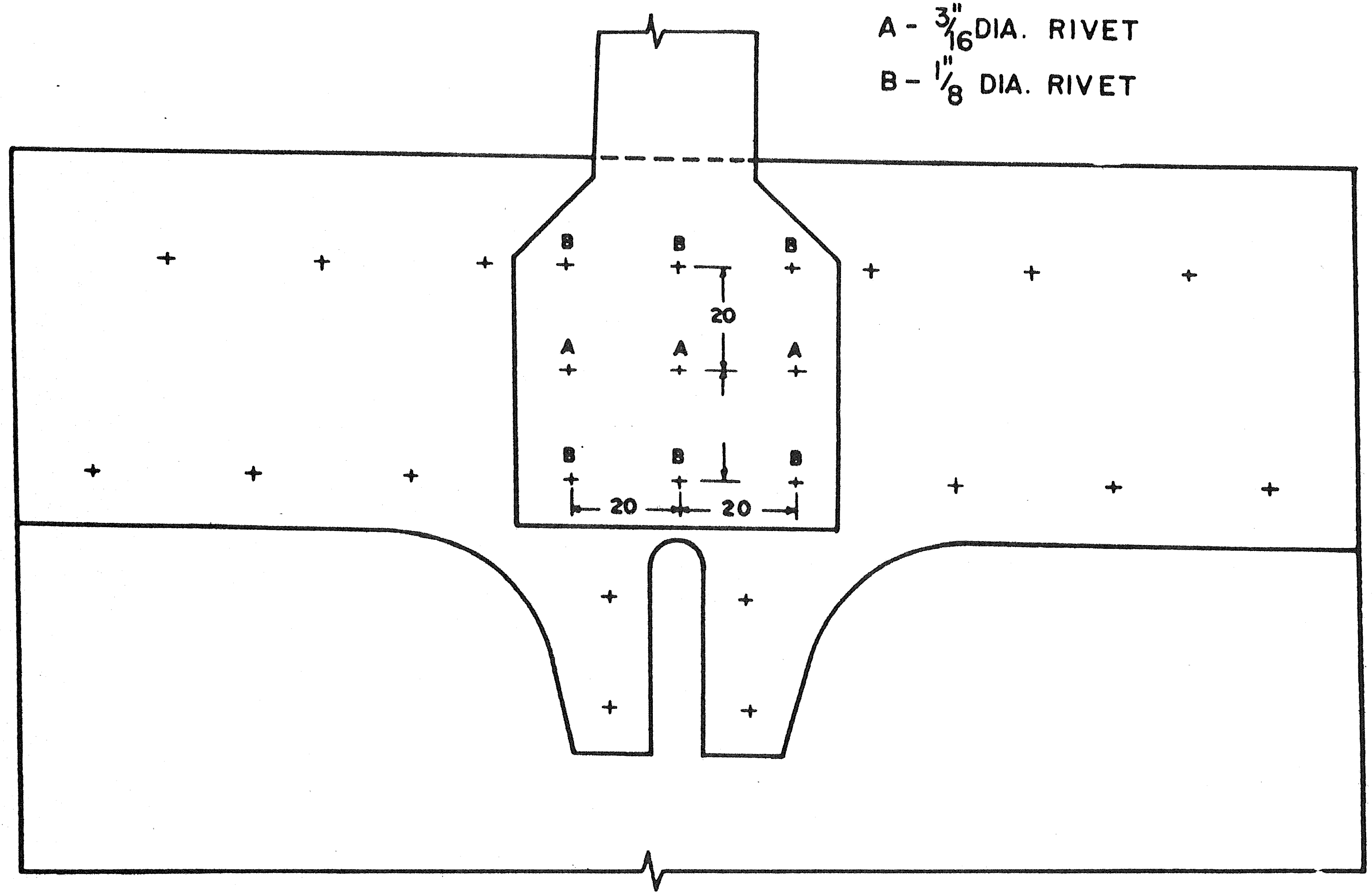

FIG. 6 . JOINT SPECIMEN TYPE '3'

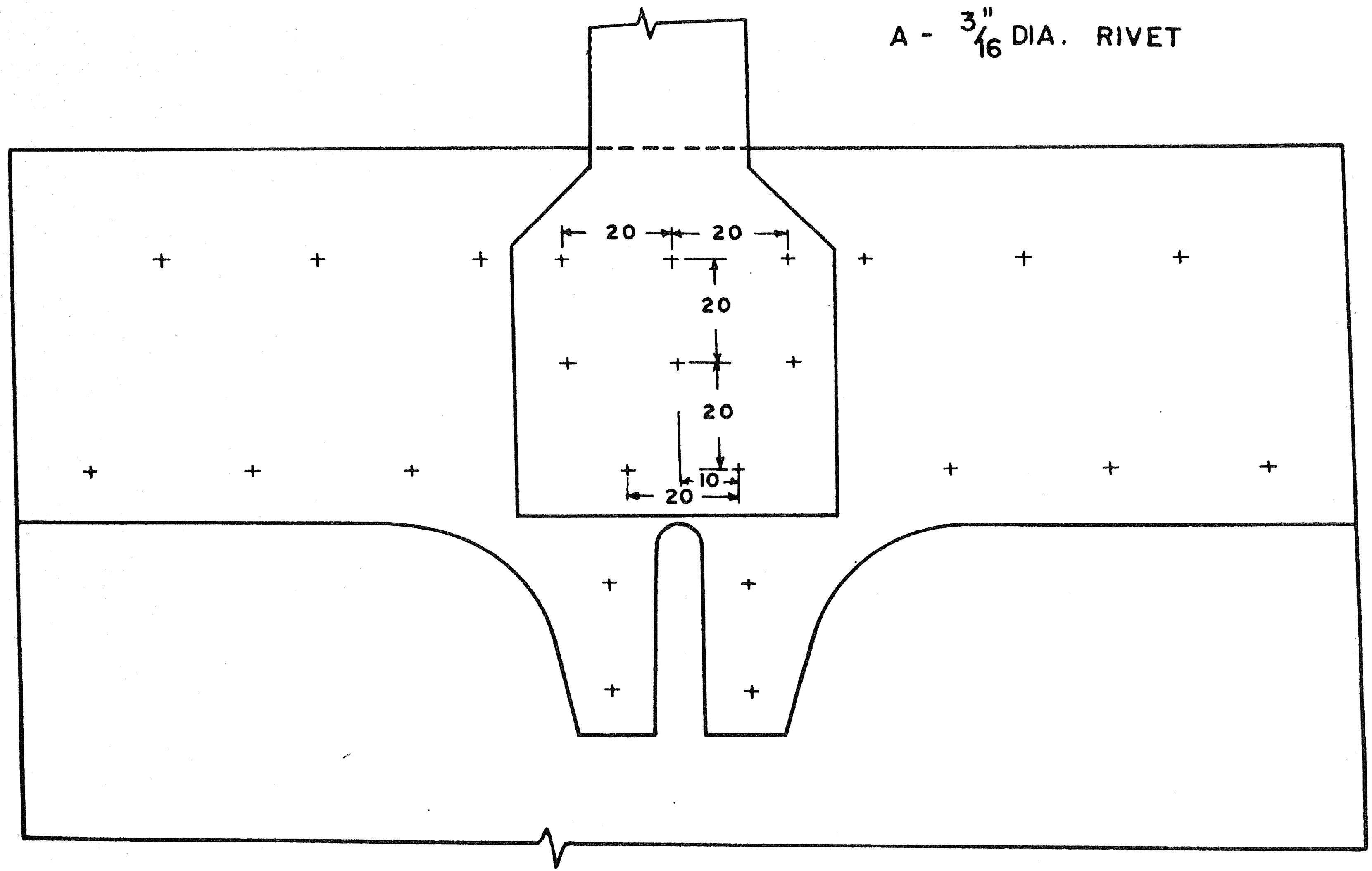

FIG. 7. JOINT SPECIMEN TYPE '4'

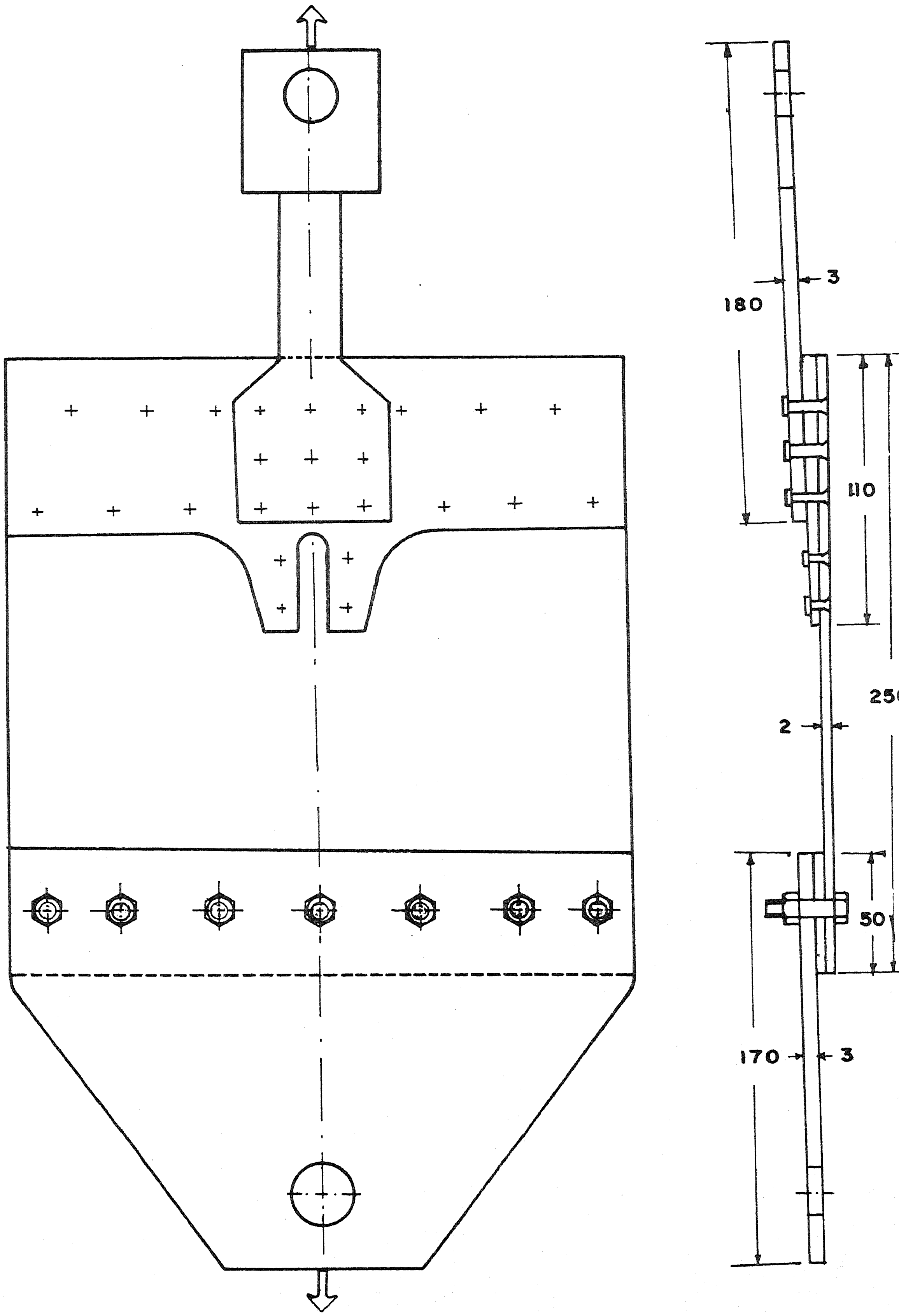

FIG. 8. JOINT SPECIMEN ASSEMBLY

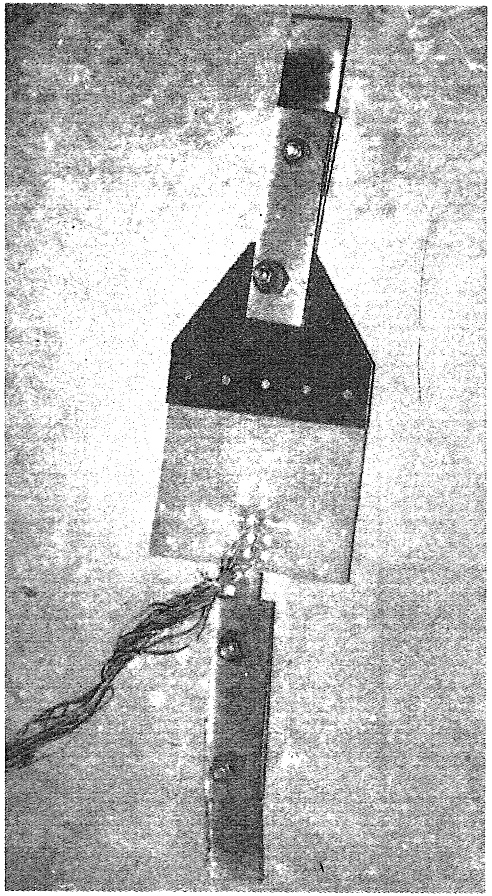

FIG. 9. PHOTOGRAPH OF THE ASSEMBLED SPECIMEN

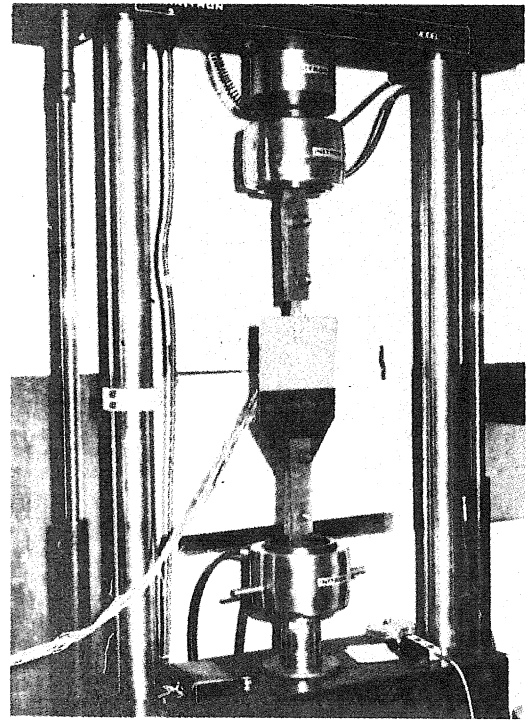

FIG. 10. PHOTOGRAPH OF THE SPECIMEN MOUNTED IN THE TESTING MACHINE

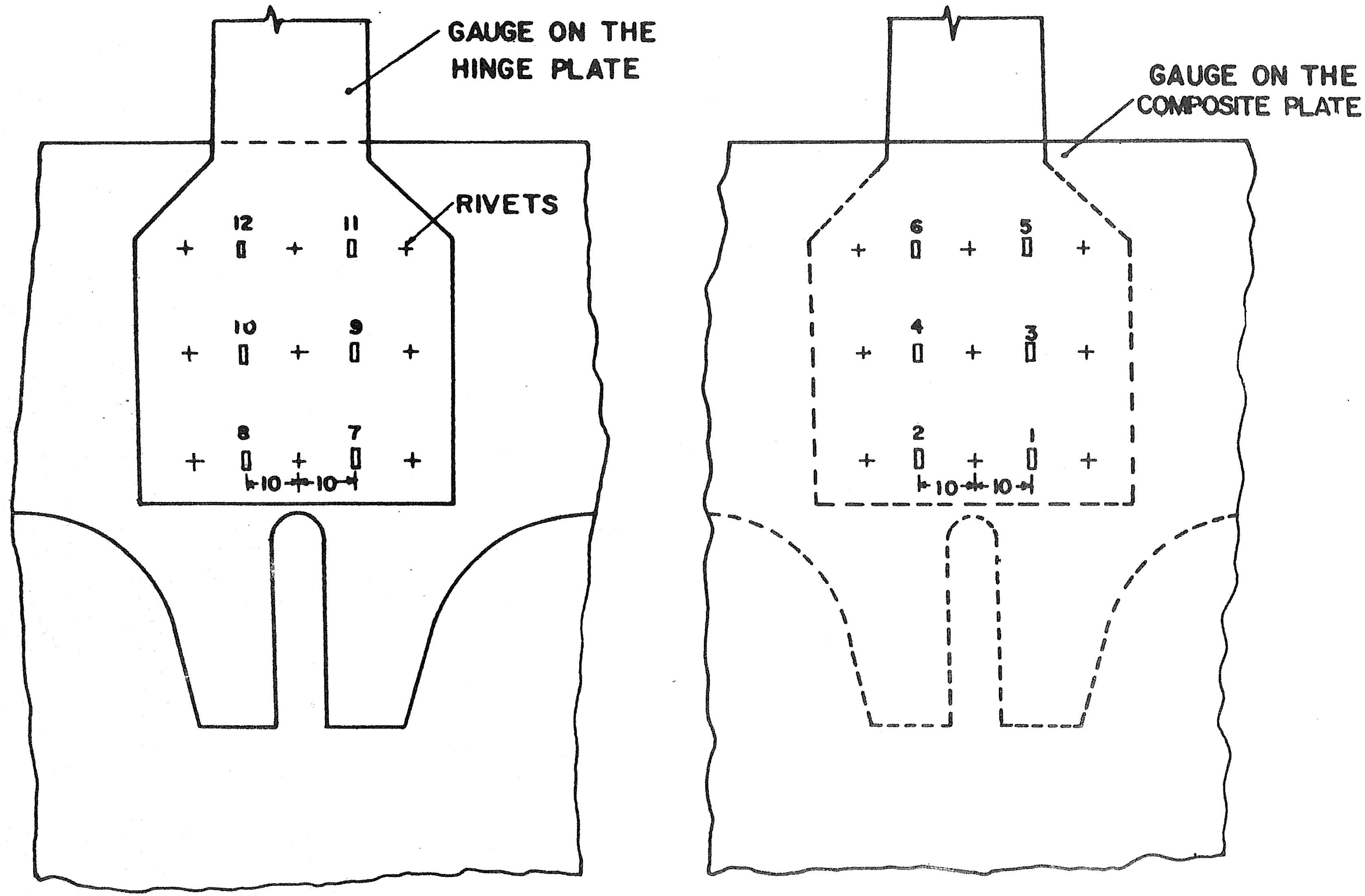

FIG. 11. STRAIN GAUGE LOCATIONS ON THE SPECIMEN

MS19

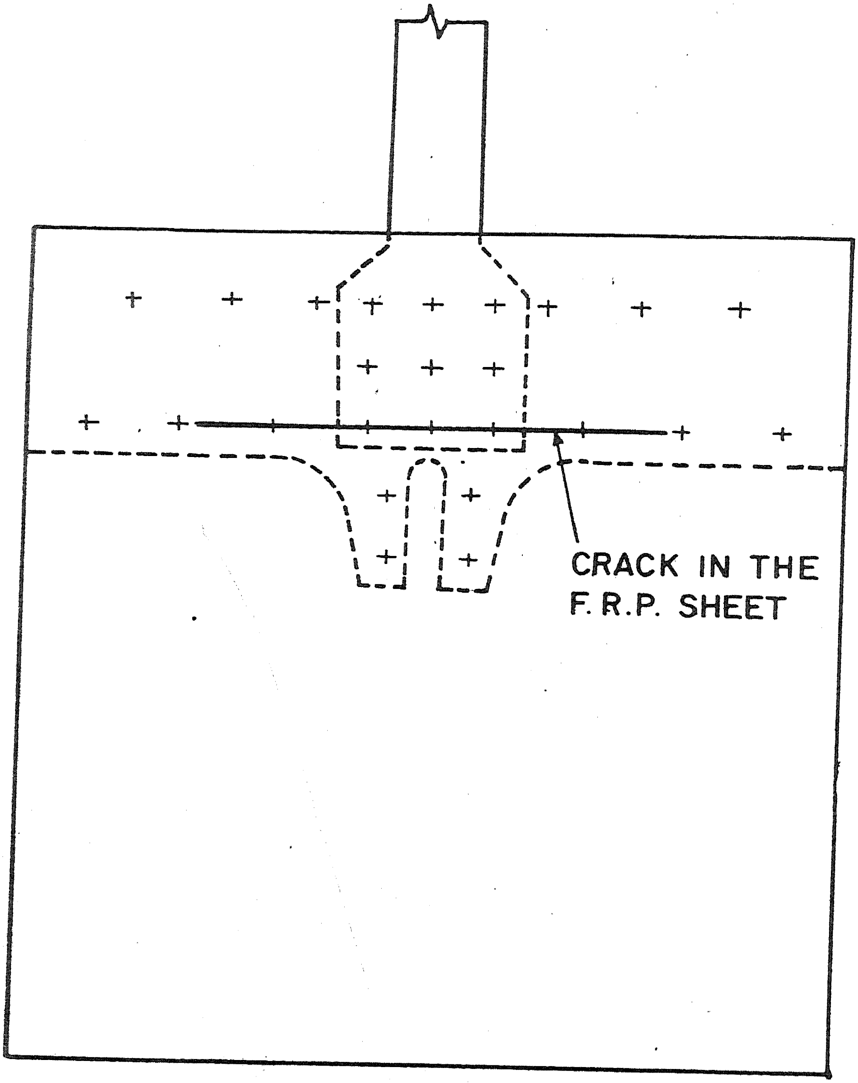

FIG. 12. TYPICAL SPECIMEN FAILURE

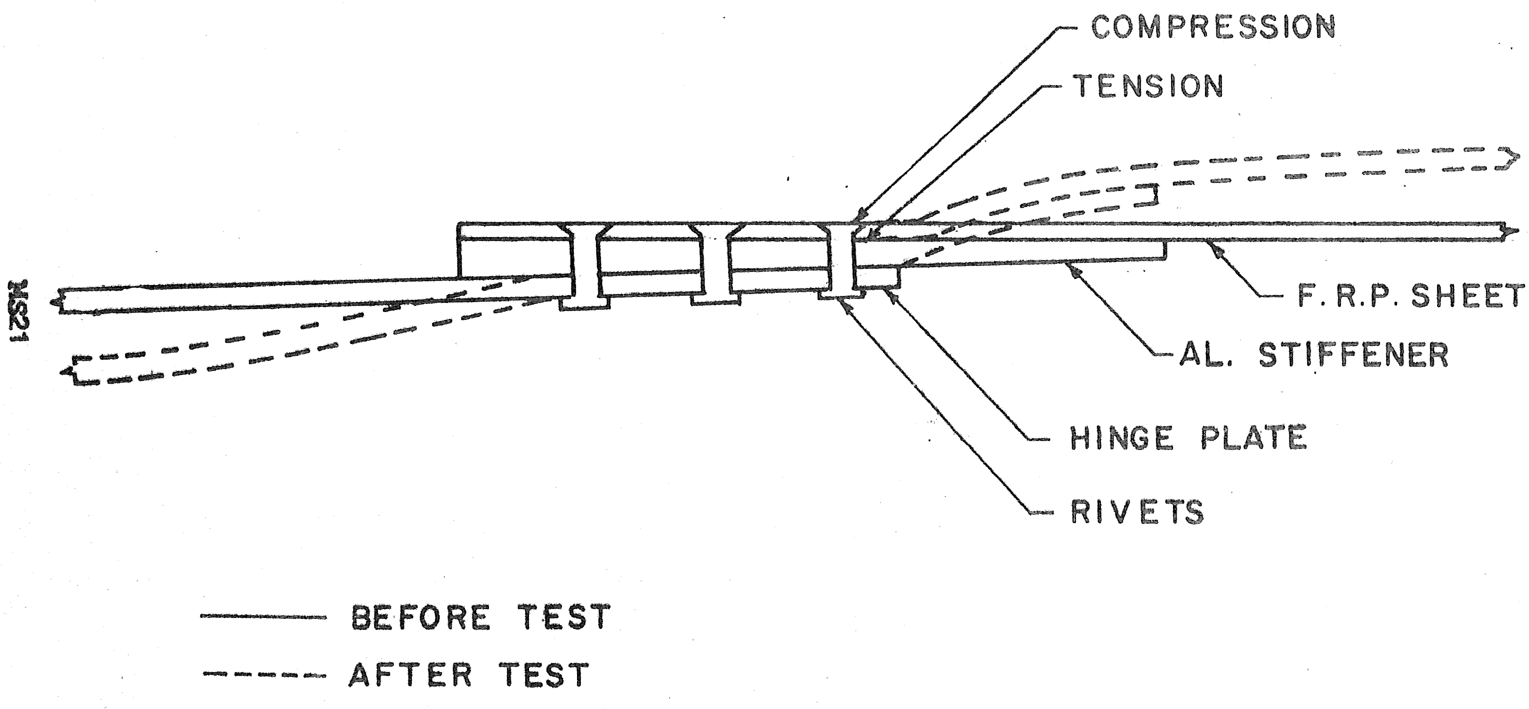

FIG. 13. TYPICAL BEHAVIOUR OF THE JOINT UNDER LOAD

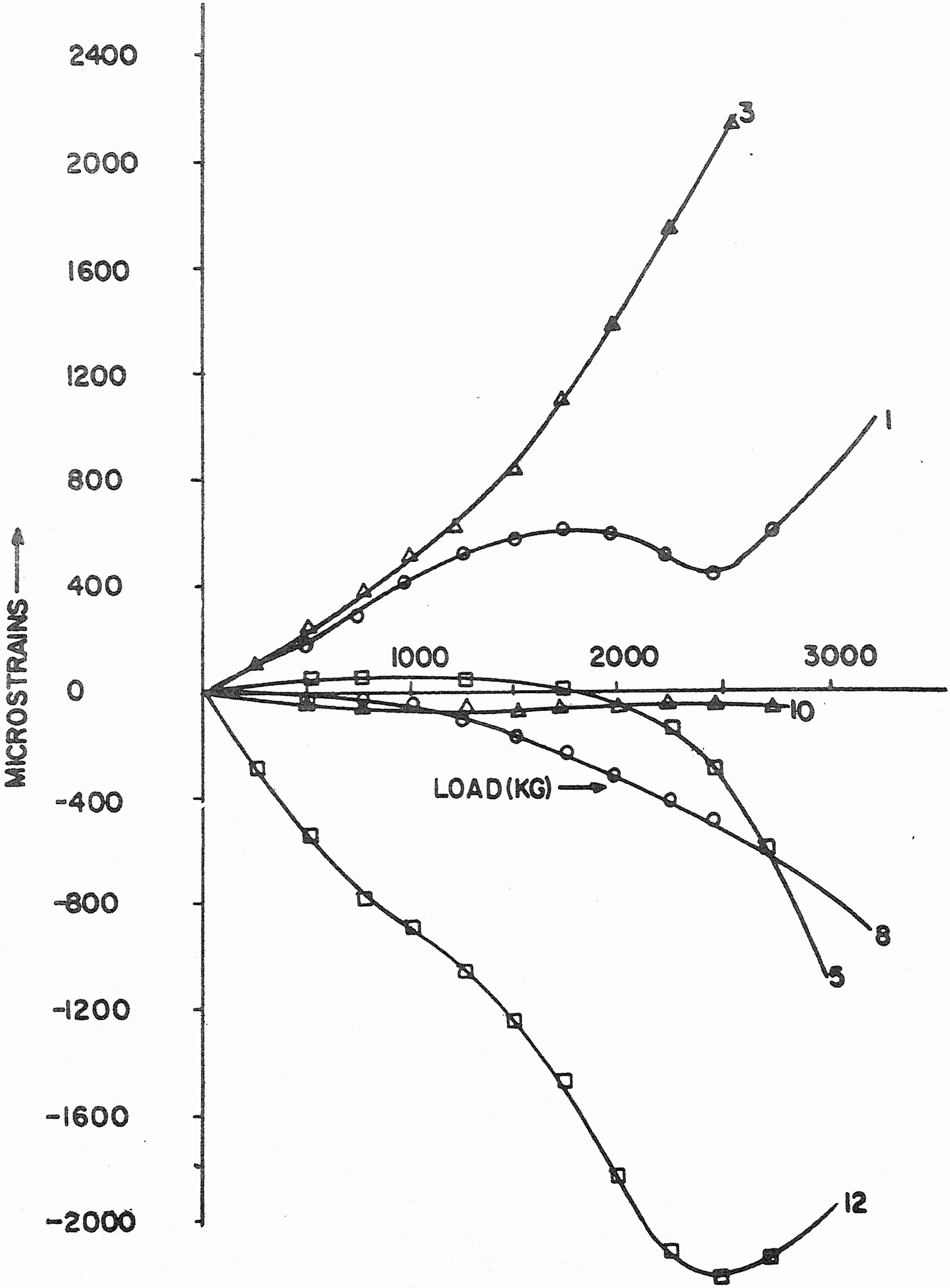

FIG. 14. STRAINS AT VARIOUS LOCATIONS FOR TYPE 'I' SPECIMEN

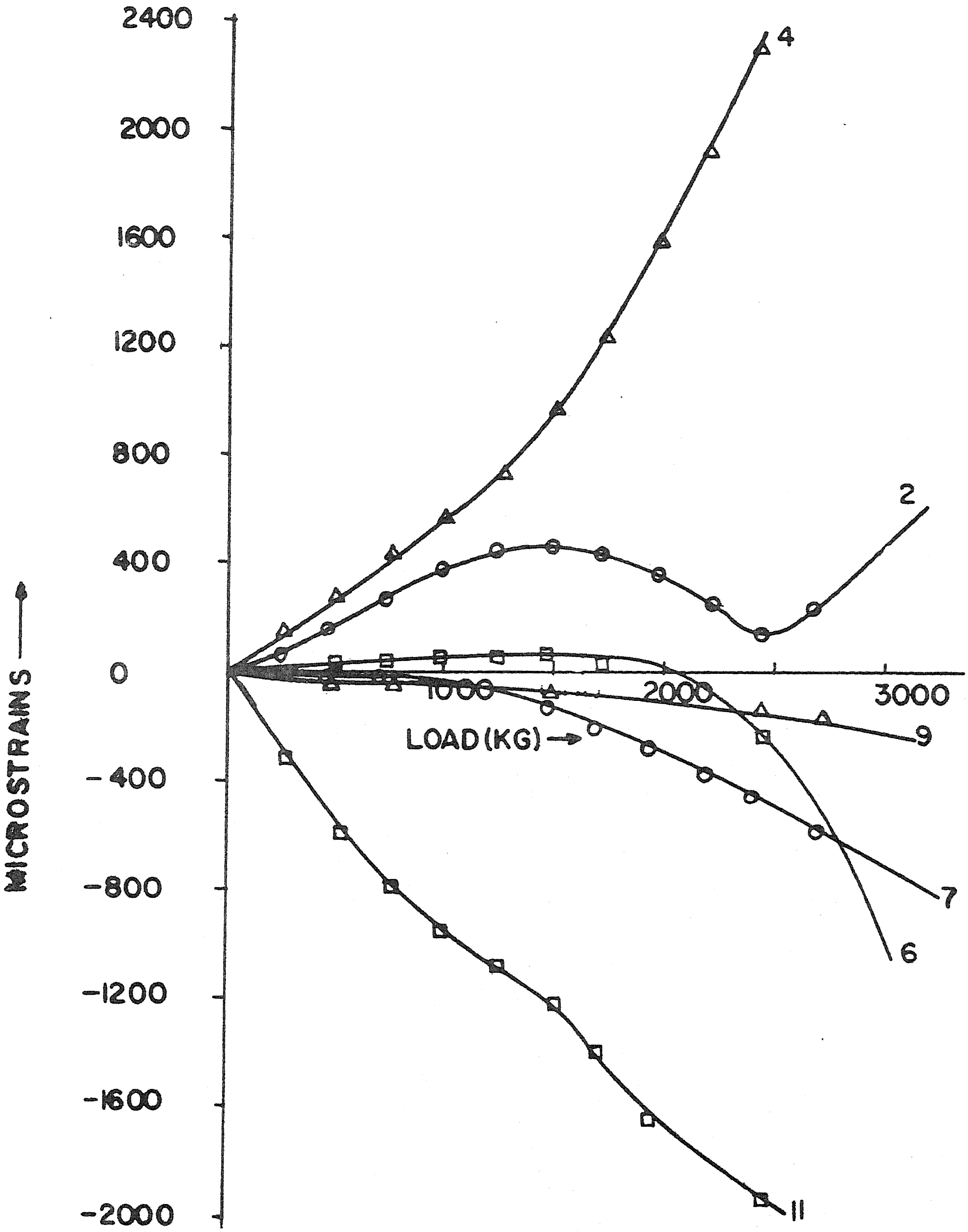

FIG.15. STRAINS AT VARIOUS LOCATIONS FOR TYPE 'I' SPECIMEN

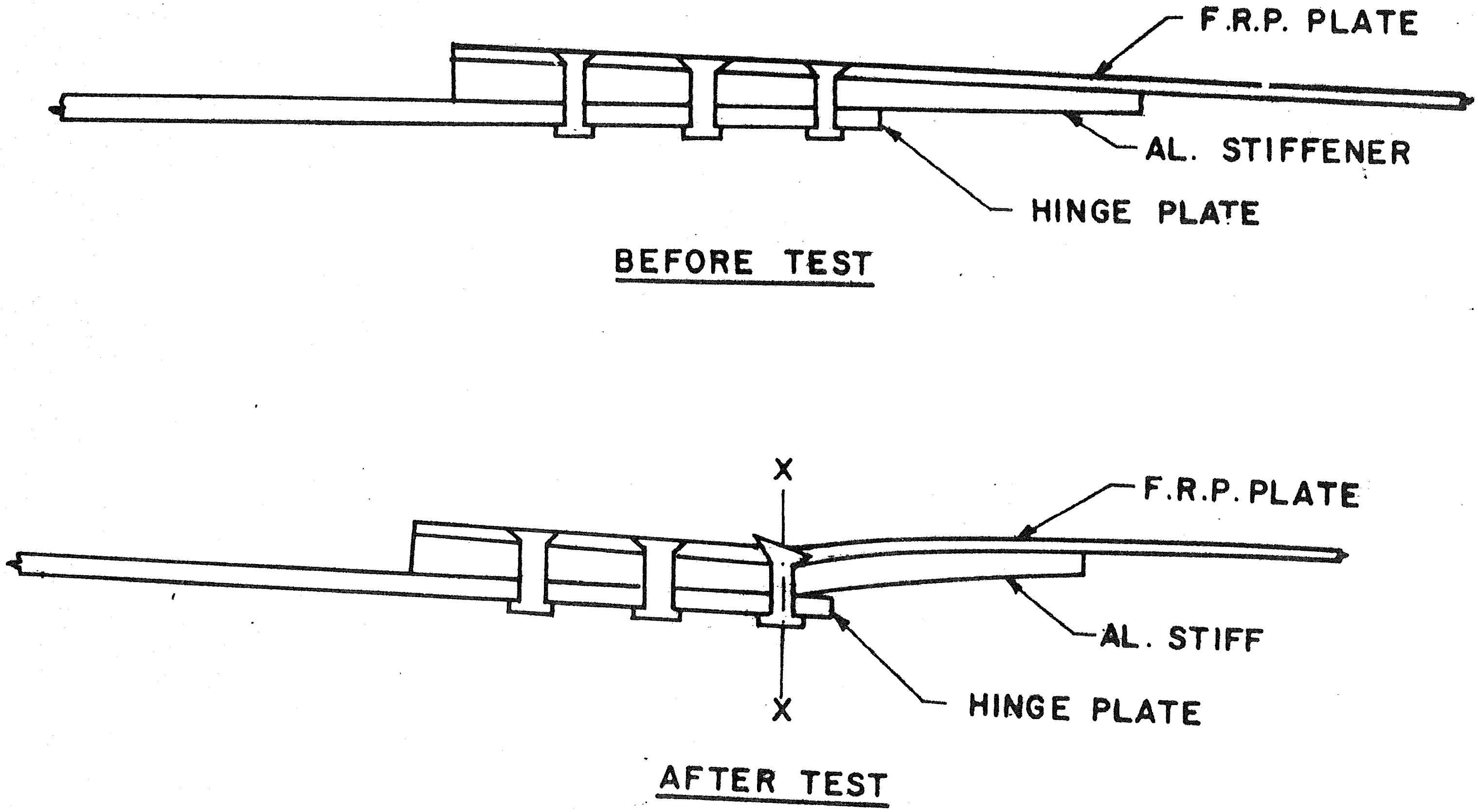

FIG.16. SOME RIVET POSITIONS BEFORE AND AFTER TEST IN TYPE 'I' SPECIMEN

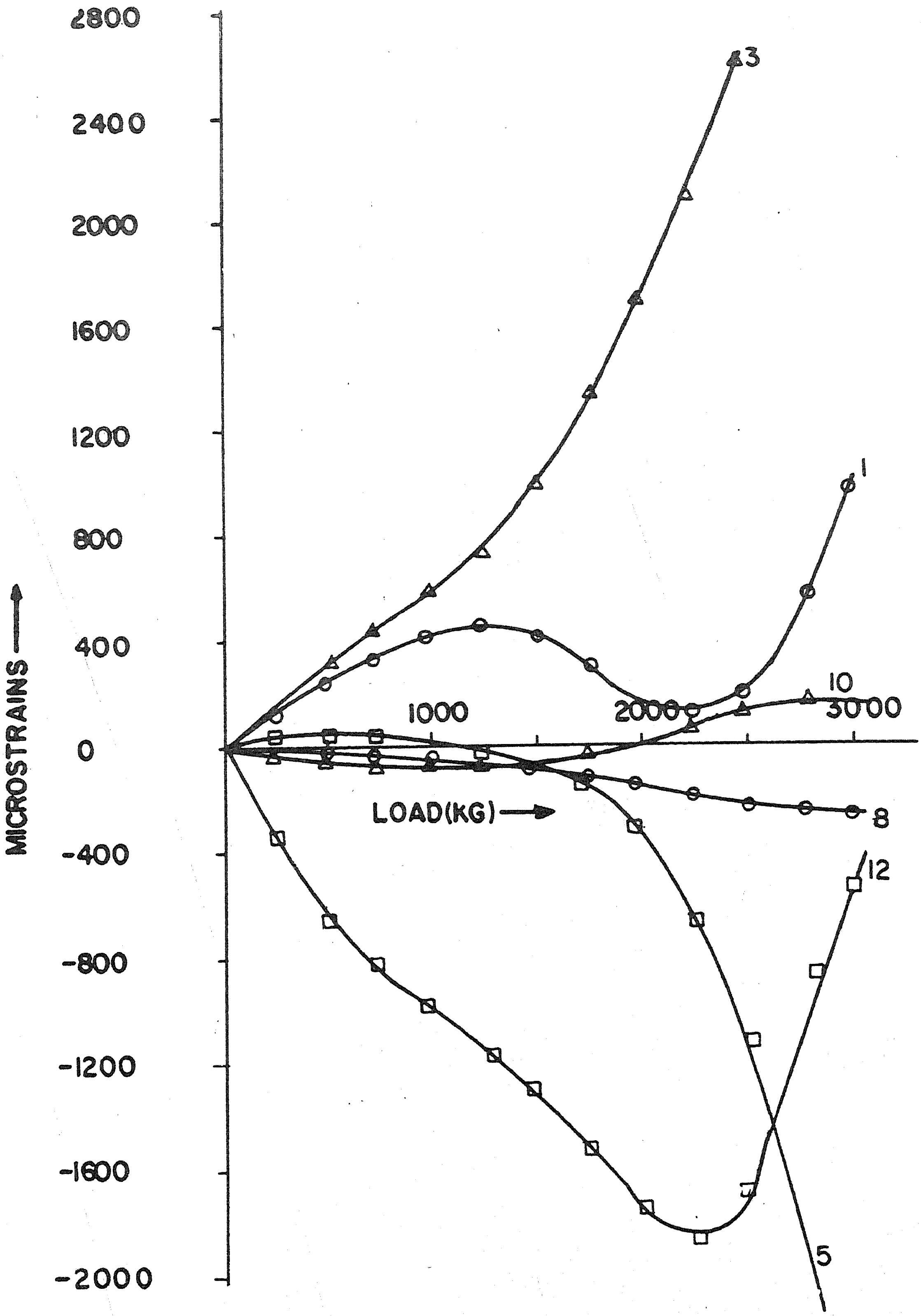

FIG. 17. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '2' SPECIMEN

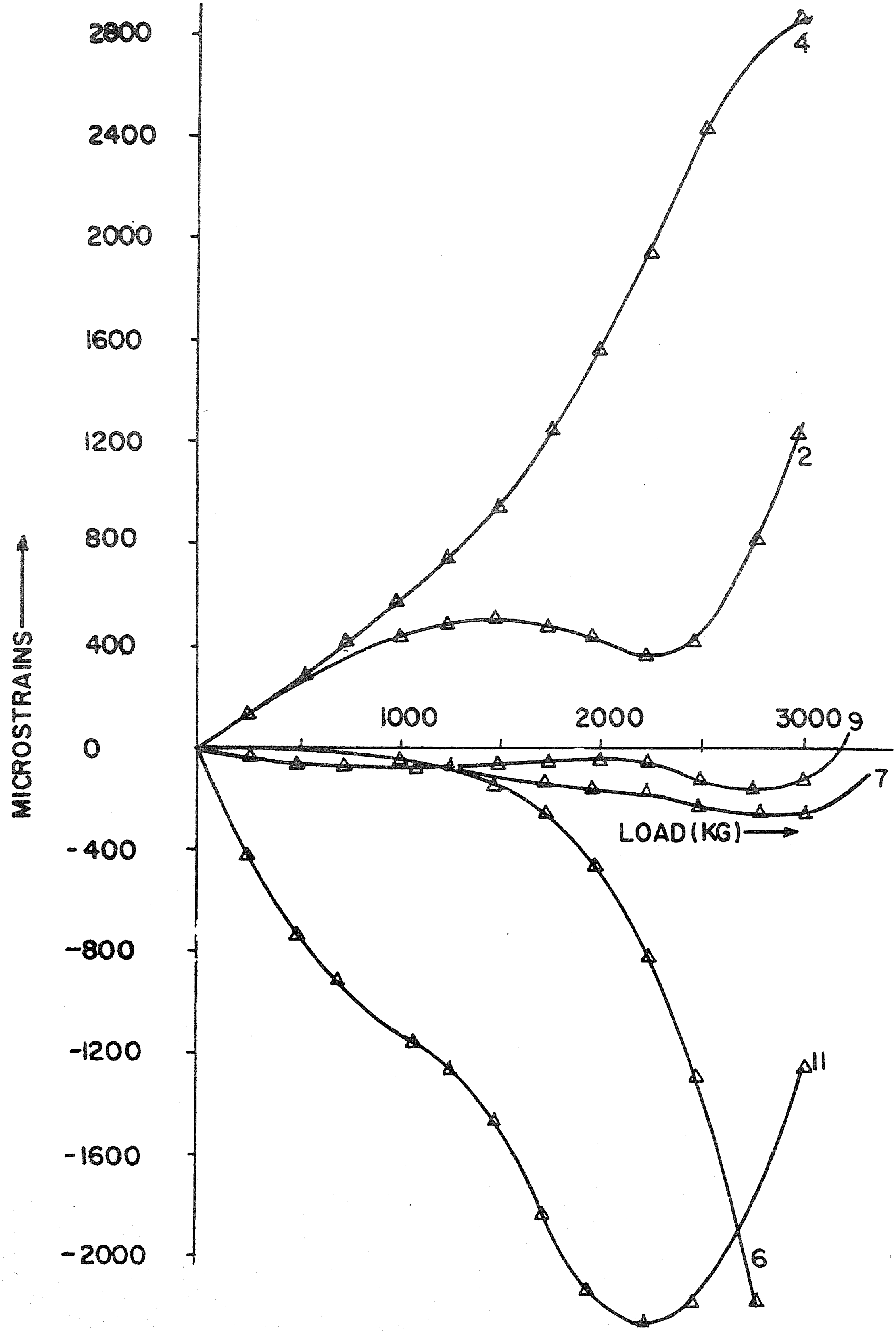

FIG. 18. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '2' SPECIMEN MS26

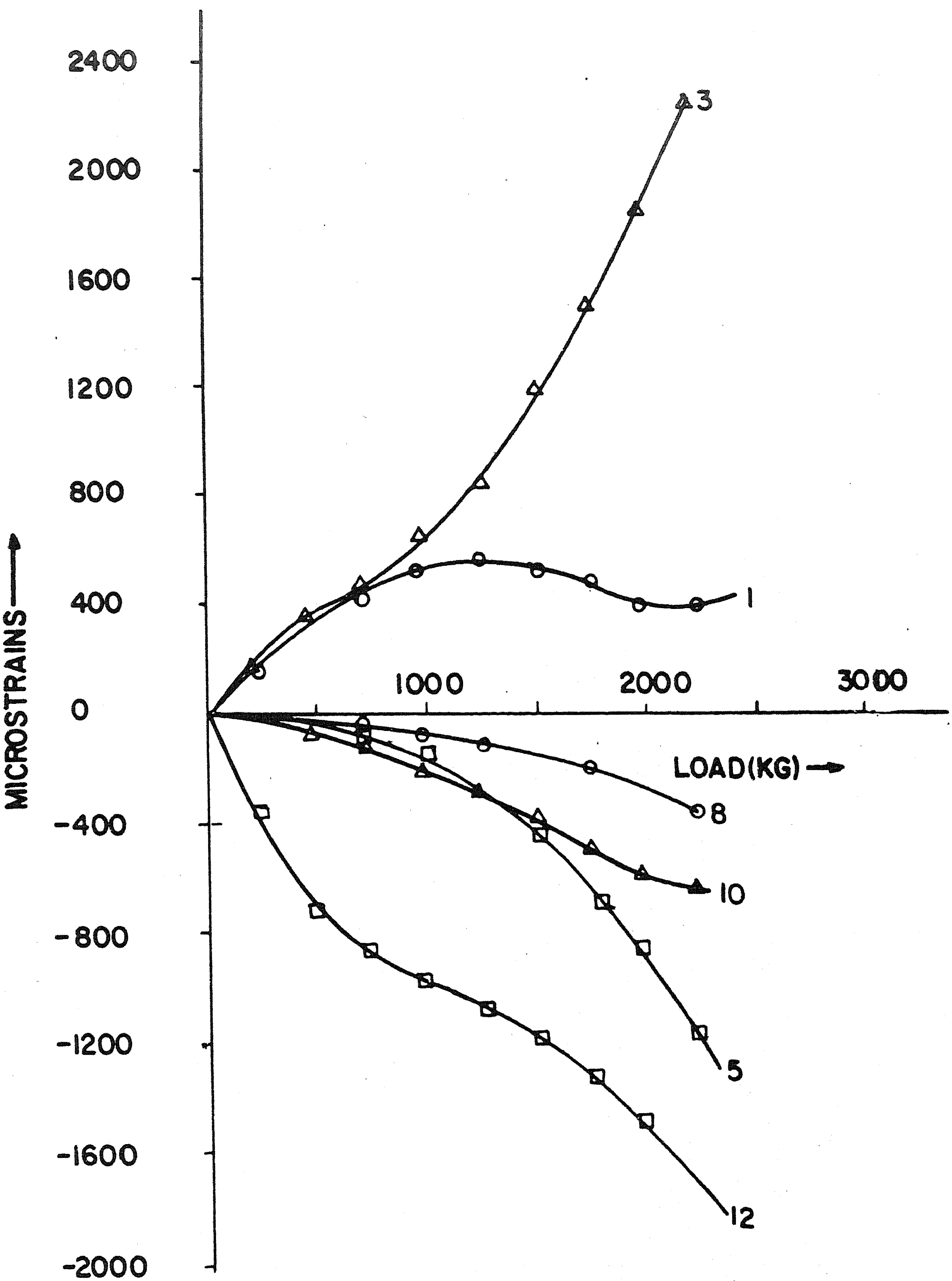

FIG. 19. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '3' SPECIMEN

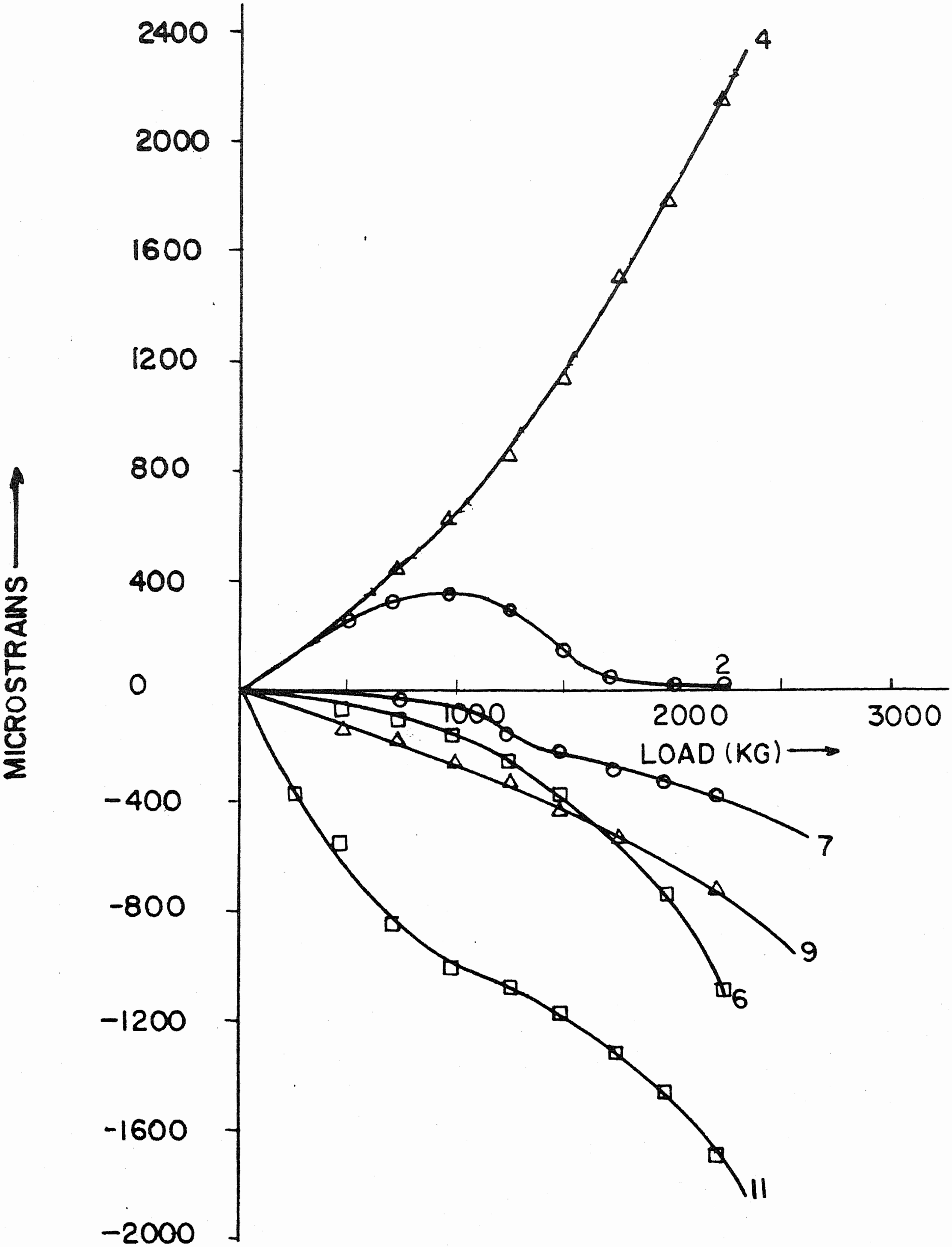

FIG. 20. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '3' SPECIMEN

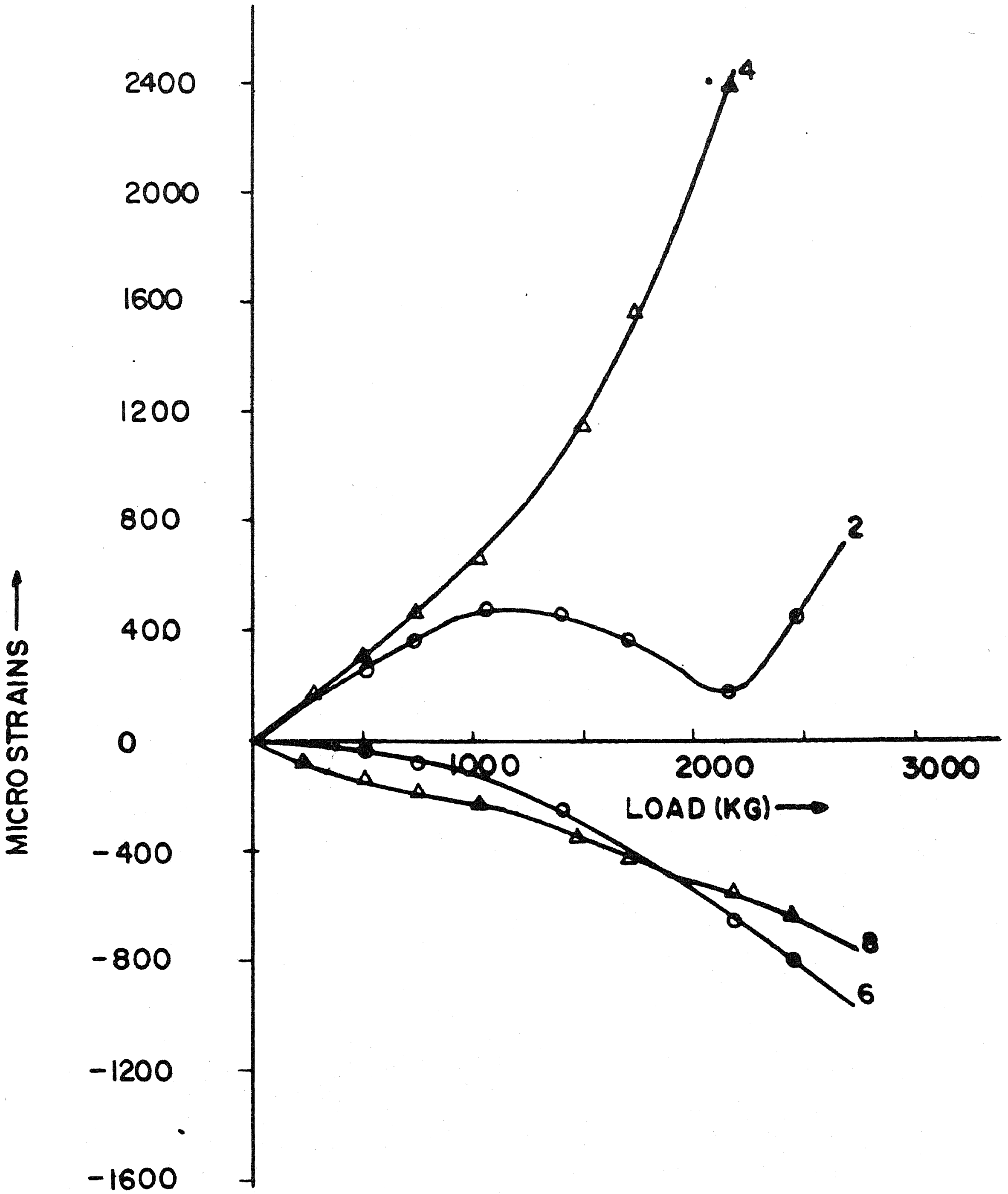

FIG.21. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '4' SPECIMEN

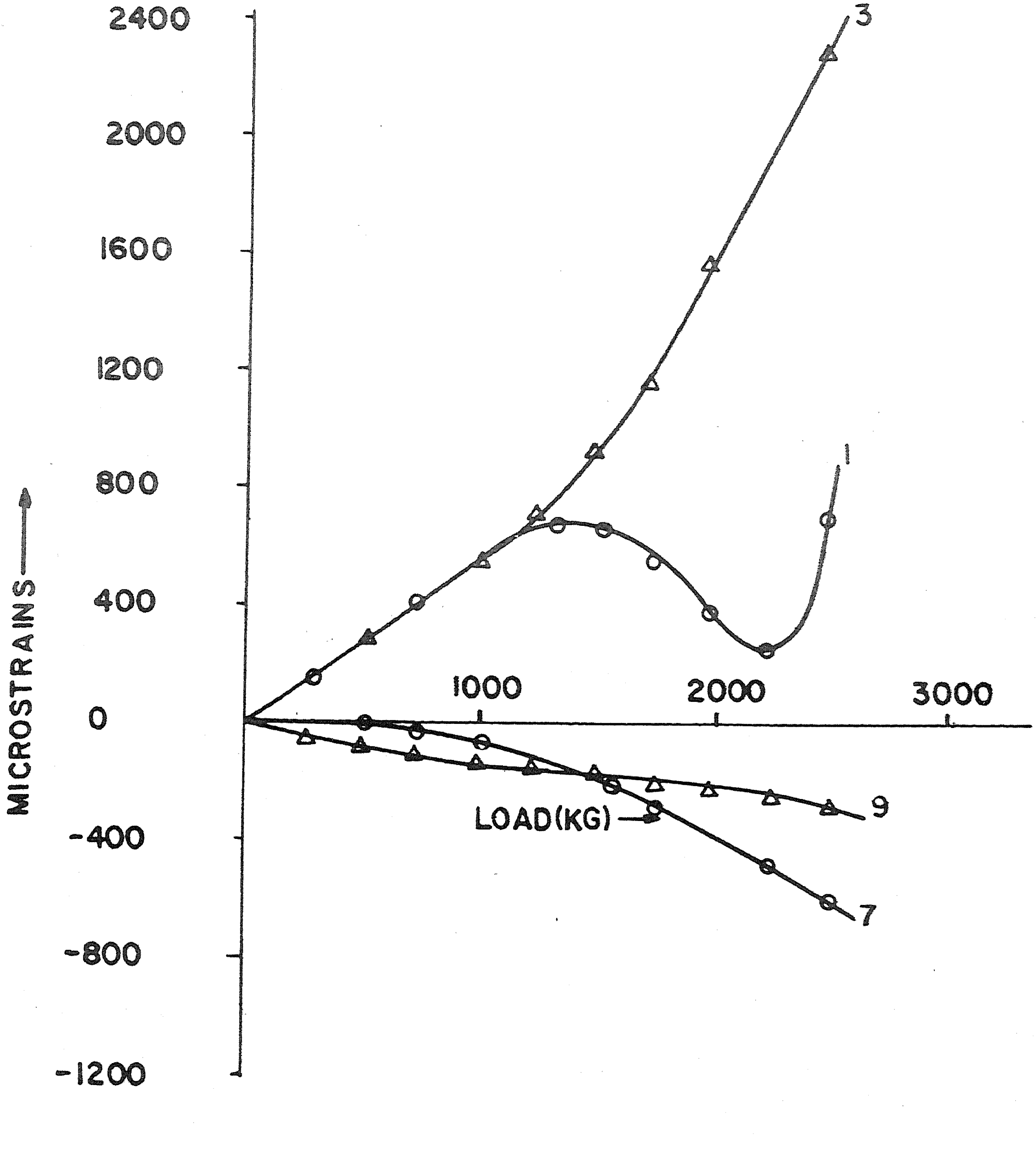

FIG. 22. TYPICAL STRAINS AT VARIOUS LOCATIONS FOR TYPE '4' SPECIMEN

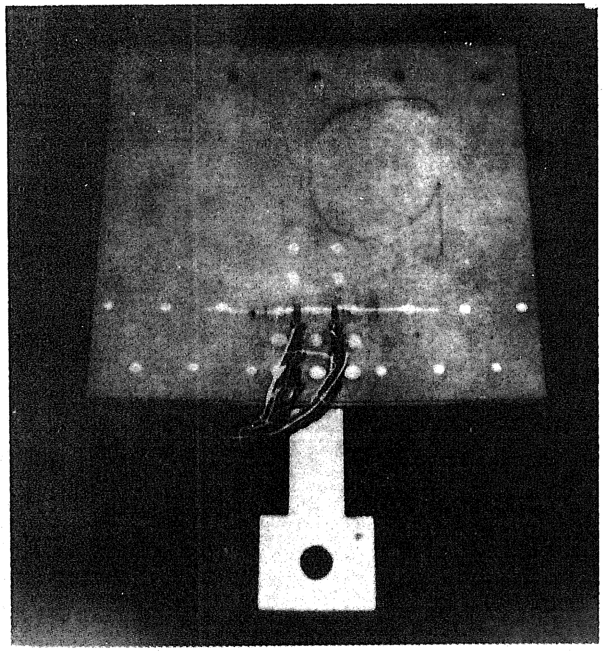

FIG. 23. PHOTOGRAPH OF THE TYPE 'I' FAILED SPECIMEN SHOWING CRACK LOCATION

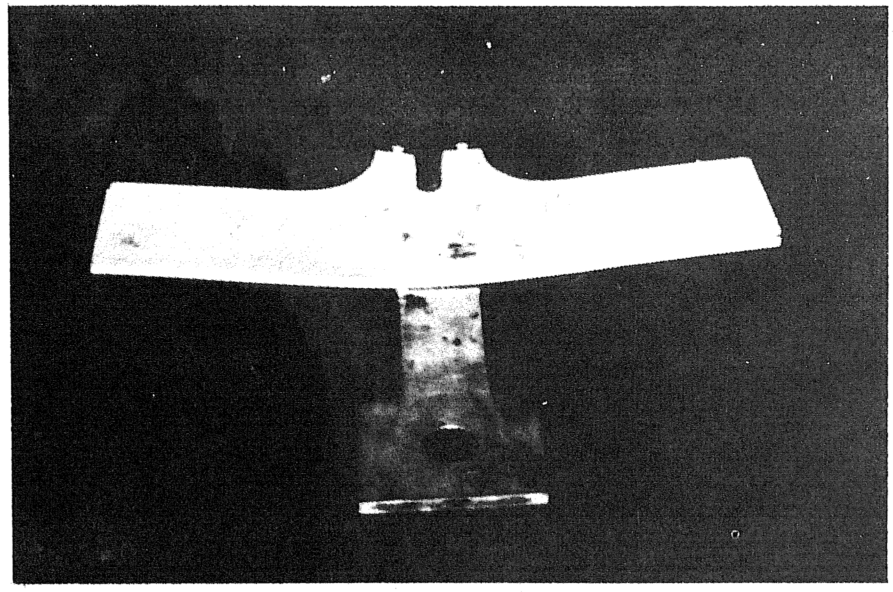

FIG. 24. PHOTOGRAPH OF THE BENT ALUMINIUM STIFFENER AFTER TEST

TABLE 1
FAILURE LOADS OF DIFFERENT TYPES OF SPECIMENS

SL. NO.	TYPE OF SPECIMEN	NUMBER OF SPECIMENS TESTED	MAX. FAILURE LOAD, KG.	MIN. FAILURE LOAD, KG.	AVERAGE FAILURE LOAD, KG.	TYPE OF FAILURE
1	1	3	3225	2750	2891	C
2	2	3	3000	2800	2933	C
3	3	3	2537·5	2225	2358	D
4	4	3	2800	2550	2700	C

C: FAILURE IN THE F.R.P. PLATE BY DEVELOPING A CRACK ALONG THE BOTTOM ROW OF RIVETS

D: SHEARING OF RIVETS